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THE CLIMATE OF CHINA[1]

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China, situated as it is along the eastern and southeastern margin of a great continent, has a climate dominated by the monsoons. These are winds which reverse in direction from summer to winter. Thus, the winds of China are prevailingly from a southeasterly quarter in summer and a northwesterly quarter in winter; that is, they tend to blow from the sea to the land in summer and from the land to the sea in winter. These monsoonal winds determine to a large extent both the ranges in temperature from summer to winter and the distribution of precipitation throughout the year. Cold winters and hot summers, especially in northern China, and the frequent droughts and floods, which occur chiefly in spring and summer, are closely tied up with these reversals of wind direction.

There are, however, many other factors which control in varying degrees the climate of China. Among these are the passage either across or very near the country of rather weak cyclonic storms, especially in spring, and the movement of typhoons, which are severe cyclonic storms much like the familiar West Indian hurricanes and which are most pronounced in September; these are felt less in northern China than in central and southern China. The rather high mountain ranges of the southeastern portion of the country and the loftier mountains and plateaus of the west and northwest modify the climate largely because of their barrier effects. This is shown by the lighter rainfall back from the coast in the southeast and by the lower rainfall and higher temperatures of the Great Szechwan Basin in summer. It is undoubtedly a fact, too, that China's winters would be more severe than they already are if it were not for the protection offered by the mountains to the west and north against the extreme cold of the interior. Fortunately for China, these cold blasts are rendered appreciably warmer by compression as they descend to the lowlands.

Finally, the control of the ocean waters over the climate of this land can not be neglected, for they not only furnish abundant vapor for the summer showers but they also serve to moderate the temperatures of summer or whenever the winds are on shore. These effects are no doubt rendered more appreciable by the warm Kuro current which moves very close to the continent at Formosa.

The reason for the monsoons of China (and they either dominate or have an important bearing upon the climate of all southeastern Asia) is at once apparent. Here is a great land mass with a great arid region in the interior just north of the Himalaya Mountains. This arid region comprises much of Mongolia, Tibet, and southern Siberia and extends far westward into Asia Minor. In winter the eastern part of this region becomes intensely cold due to rapid radiation from the land because of the clear, dry air. Thus, the air here is relatively dense as compared with the moist, warm air over the ocean waters to the south; that is, the barometric pressure over the land is "high" while that over the ocean is "low." Hence the air over the land tends to move in a southerly direction, in so far as China is concerned, and to replace the warmer and moister, and hence lighter, air over the water. In summer, however, conditions are reversed, although contrasts are not so great. The land over the interior under the intense insolation which results from the longer days, from the more vertical rays of the sun, and from the absence of moisture, becomes relatively hot. The air is greatly heated and expanded. Its density therefore is much less than that of the air over the relatively cool ocean to the southeast. Hence a high-pressure area forms over the ocean and a low-pressure area over the land, with a resultant movement of the air from the sea to the land.

The story is not quite so simple as this would seem to indicate. The barometric pressure over the land is not consistently high in winter and low in summer; it is evident, too, that the change from summer to winter conditions and vice versa are not abrupt. Many factors enter in to modify this ideal distribution of pressure during the winter and summer seasons. It follows, then, that the winds are somewhat variable.

The data on wind directions, as well as the other climatological elements, are very meager. Co-ching Chu, of the National Southeastern University at Nanking, in his study of the climate of Nanking, suggests that the wind directions of North Saddle Island, a small island near the mouth of the Yangtze River, may be taken as fairly indicative of wind directions all along the east coast. These show that in January winds blow 50 per cent of the time from the northwest and hence only 50 per cent of the time from all other directions combined, in April they blow 55 per cent of the time from the northeast and east, in July 50 per cent of the time from the southeast and south, and in October 50 per cent of the time from the north and northeast. Winds rarely blow from the west, and very infrequently from the southwest. This is in striking contrast to the eastern portion of the United States. Local topography, the presence of land and sea breezes, and the passage of cyclones and typhoons would prevent these conditions from obtaining throughout China. The few other records available seem to show much the same wind distribution as at North Saddle Island. Thus, the winds in July at Cheefoo seem to blow mainly from a southerly direction and in January from a northwesterly direction; at Amoy they are from a southerly direction in July and from a northeasterly direction in January.

The most marked effects of the monsoonal winds are shown, of course, on the annual range of temperature and precipitation. Because of these outflowing winds in winter, all China shivers down to the tip of its toes—even to Hong Kong, the world's coldest subtropical city. Conversely, the inflowing winds of summer give to the country a very thorough and uniform roasting in July and August. It is a land, then, of remarkable contrasts

[1] Cf. Co-Ching Chu, Rainfall in China. MONTHLY WEATHER REVIEW, 44:276-281.

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between winter and summer; these contrasts modified only to a slight degree by the influence of local topography.

These contrasts are most intense in the north, where the severity of the winter is extreme. Mukden, situated in the same latitude and at about the same distance from the coast as Albany, N. Y., has a January mean temperature of only 8°, some 15° colder than its none too tepid American counterpart. Likewise, Tientsin, about the same latitude as Washington, has a January mean 8° colder. In fact, this comparison between stations in China and similarly situated stations in the same latitude in the United States can be carried throughout the whole length of China, and will serve to emphasize the severity of the Chinese winter. Thus, Shanghai on the central coast is 14° colder in winter than Savannah, Ga., its latitudinous American partner. And Hong Kong, on the southern coast, whose coldest month is February with a mean temperature of 58° is some 10° colder than Key West, although the latter is about 3° north of Hong Kong.

Possibly, although we have not had the opportunity to investigate thoroughly, the only advantage that the Chinese cold has over the better known American variety, is its steadiness. The rapid changes from hot to cold, the "bathing suit to fur coat" type so well associated with our New England climate, do not seem to occur so frequently. This appears to be true in the north especially, as the highest temperature recorded at Mukden in January in 10 years was 46°, while temperatures above 60° are not infrequent at Albany. Very likely this is because of the weakness of the winter cyclonic action in northeastern China as compared with that in the northeastern United States. Thus, in China the wind in the coldest months does not blow long enough or strong enough from the south to bring large quantities of warm air very far north, and the rise of temperature on the front of a weak Chinese "low" is not nearly so great as the rise in front of one of the intense "lows" that pass along our northern border in winter. Even if northern China is spared in this respect, yet the steady cold and dryness bring hardship and suffering. In the vicinity of Peking the fierce north winds swoop down upon the city laden with clouds of dust that make life barely endurable, and even at times sweep out to sea and interfere with navigation. And this past winter brought the story of the draft of 200 coolies brought down in open cars from the vicinity of the Great Wall to Peking for work about the city. On arrival they were all shipped back as unsatisfactory; they were all frozen to death.

Farther south in Central China where a southerly wind can more readily raise the temperature, cold waves apparently occur. Thus, in Nanking in 1916 the temperature fell from 50° on January 23 to 13° on the 24th; this drop of 37° comes within our conception of a cold wave. Yet even here the weather remains cold or warm for longer periods than with us. In the northeastern United States the weather unit is two or three days (that is, normally a change in the type of weather is expected every two or three days), while at Nanking it would appear to be a week or 10 days.

A striking fact to be noted is that the central western interior of China is considerably warmer than the eastern coast at the same latitude. For instance, Chengtu in the Szechwan Basin at an elevation of 1,700 feet has a January mean 6° higher than that of Shanghai; and Chungking, in the same region but a little farther south of Chengtu, is 8° warmer than Hangchow on the coast. The eastern coast is open to the uninterrupted sweep of the north winds; but mountain ranges, especially the Tsin Ling Shan, that thrust themselves out eastwardly from the Tibetan Highland as far as the central Honan Province, protect the western sector.

Cold as the winter is, yet spring comes quickly. By February 27 spring has come to Nanking (officially a mean temperature of 43°). By March 26 it has arrived at Cheefoo, and by April 8 at Mukden. This is a rate of advance almost twice as fast as that experienced in the eastern United States. According to Doctor Hopkins, spring advances northward in the United States normally at the rate of 4 days for each degree of latitude; in China the rate is about 2½ days. Chu, in his paper before the recent meeting of the Pan Pacific Science Society, pointed out the interesting fact that spring months—April, May, and June—average about 2° cooler at Shanghai than at Tientsin, which is 500 miles farther north. This anomaly is caused by the depressions which frequently passing down the Yangtze Valley during these months, bring rain and cloudy weather to Central China, but leave north China unaffected.

Spring passes rapidly into summer, and by June practically all stations show mean temperatures of 70° or over, and with July and August come the months of greatest heat over the whole country. These two months show little variation between northern and southern stations. Thus, the July mean at Hong Kong is 82°, at Chungking 82°, at Nanking 81°, and at Mukden 76°. A comparison with the United States shows that northern China is warmer in summer than the corresponding region of the United States; but in the center and south they are about the same. For example, Mukden and Tientsin with mean temperatures of 76° and 79° are, respectively, warmer than Albany and Washington with 73° and 76°; but Nanking with a July mean of 81° is about the same as Savannah with 82°, and Hong Kong with 82° is slightly cooler than Key West with 83½°. In spite of the high mean temperature, absolute maxima of 100° or more are rare. Of the 100 stations reporting at Zikawei Observatory, only 29 have ever reported temperatures as high as this. Of these, the stations in the Szechwan Basin and those around Peking vie with one another in reporting the high temperatures: Ichang and Chungking each have reported temperatures as high as 110°; in northern China, Tangwang has reported 113°, Hienchien 111°, and Tangku 118°, but this last reading is open to suspicion.

It is in summer that the ocean exerts its influence most in affecting the climate of China. Since the winds are prevailingly on shore, the temperature along the shore is everywhere lower than the immediate interior.

After September the thermometer begins to tumble almost as rapidly as it rose in the spring. By November China has become considerably colder than the United States. Mukden is then 10° colder than Albany, Tientsin 5° colder than Washington, and Shanghai 7° colder than Savannah. By December China is once more in the relentless grip of winter. The monthly averages for five places are presented in the diagrams below.

The rainfall of China is quite as remarkable as the course of temperature. As would be expected, a region exposed to cold, dry winds blowing from a high interior plateau would have little if any rainfall while those winds prevailed. On the other hand, winds coming from a moist ocean and blowing across the higher land would certainly cause rather abundant precipitation. Through-

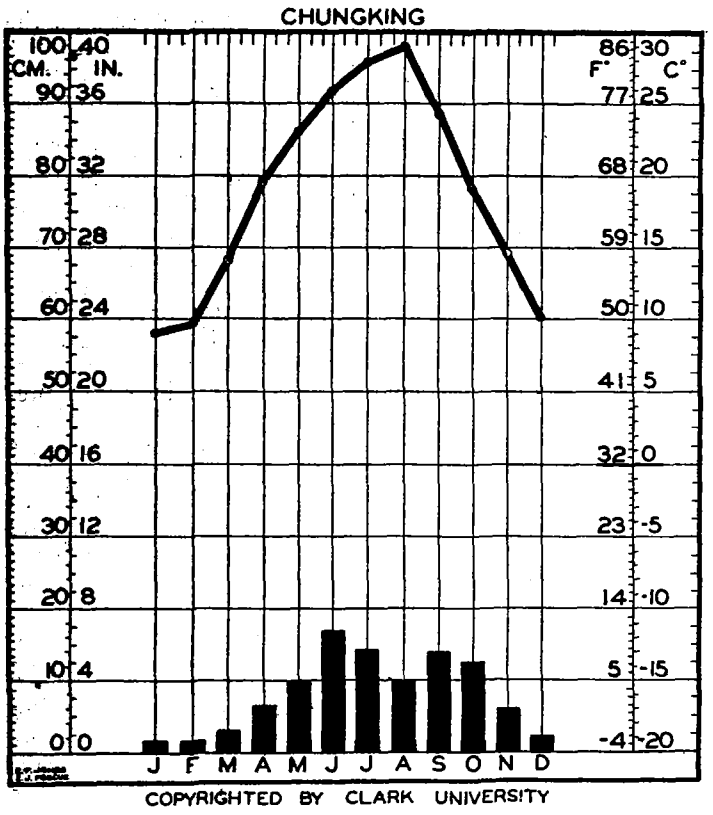

FIG. 1.—Monthly mean temperature and total precipitation at Chungking

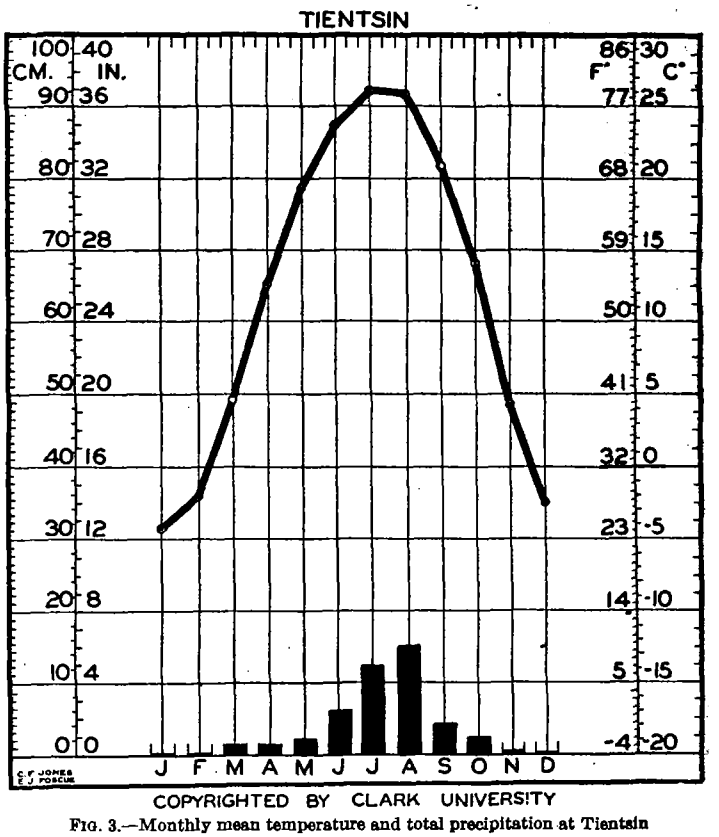

FIG. 3.—Monthly mean temperature and total precipitation at Tientsin

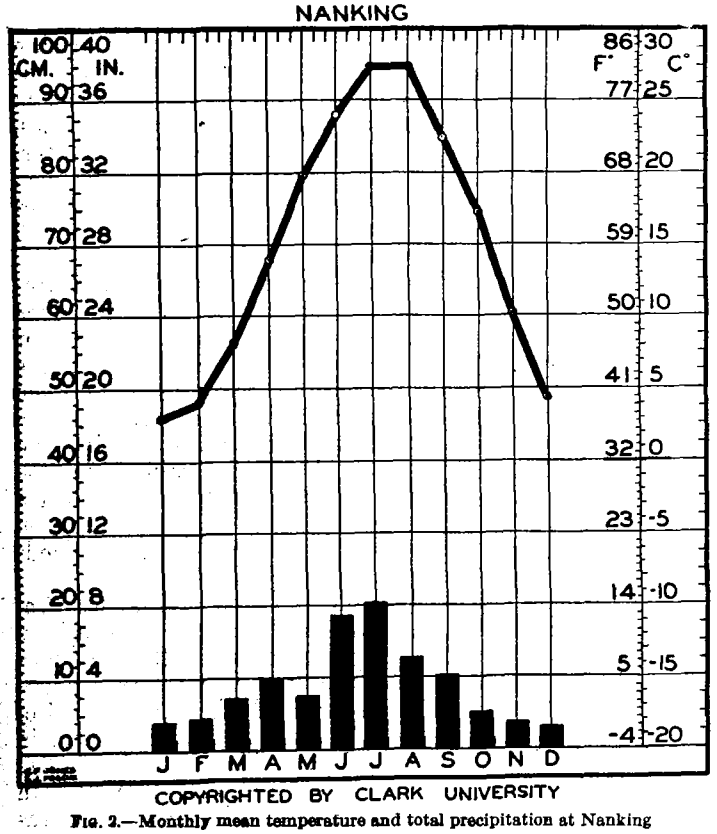

FIG. 2.—Monthly mean temperature and total precipitation at Nanking

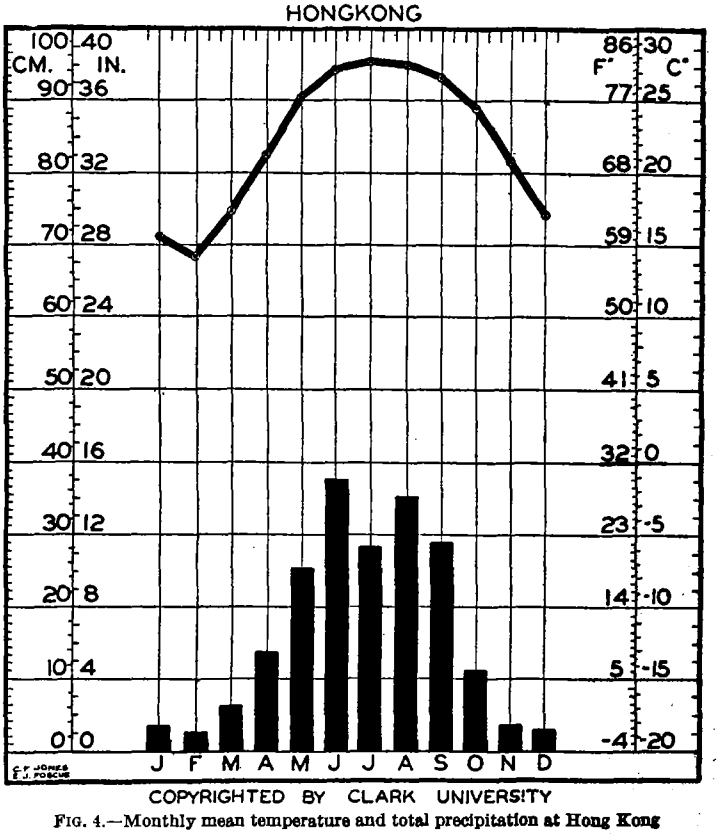

FIG. 4.—Monthly mean temperature and total precipitation at Hong Kong

out the nation the latter condition generally obtains in summer and the former in winter.

It can be readily seen from the accompanying maps of the mean annual rainfall, as well as from the graphs, that the rainfall (including some snow in the north) increases from north to south, and that it is much the heaviest during the three summer months. It may also be noted from the graphs that the three winter months in Mukden and Tientsin on the average are relatively dry, scarcely no rain or snow falling. These cities receive only 3 per cent and 2 per cent, respectively, of the total annual precipitation during the winter, while they receive 60 per cent and 72 per cent, respectively, during the three summer months. Compare these percentages with the similarly situated American cities: Albany receives 20 per cent of its total in winter and 30 per cent in summer; and Washington, with an annual precipitation of just

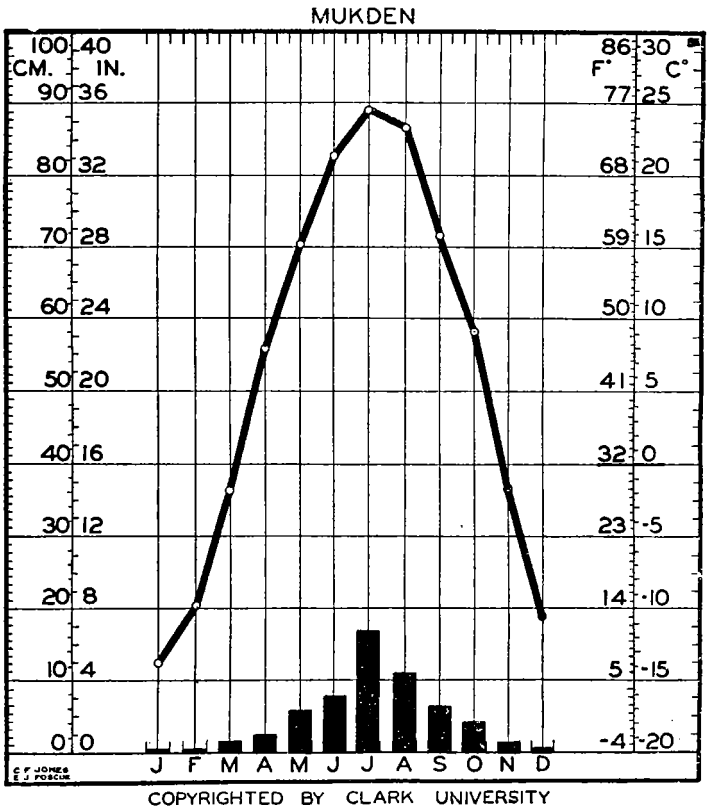

FIG. 5.—Monthly mean temperature and total precipitation at Mukden

twice that of Tientsin, receives 23 per cent of its total in winter and 30 per cent in summer.

The story is still different for Nanking and Montgomery, Ala., both of which have the same latitude, are located some distance inland, and have about the same annual rainfall. For Nanking it is 11 per cent of the total in winter and 48 per cent in summer; for Montgomery it is 30 per cent in winter and only 25 per cent in summer.

It will be interesting to compare further two other stations which have the same latitude and which are considerable distances inland: Chungking, about 600 miles from the South China Sea, and San Antonio, about 150 miles from the Gulf of Mexico, both have rather high plateau areas to the west. Chungking receives only 6 per cent of its total rainfall in winter, while San Antonio receives 17 per cent; for the three summer months the percentages are 41 and 25, respectively. Yet Chungking is reported to be perpetually cloudy, so much so that the dogs there bark when the sun appears. Even subtropical Hong Kong receives only 4 per cent of its nearly 90 inches of rain in winter, while its American counterpart, Havana, gets 14 per cent for the same period.

These figures are striking. Yet every station in China shows that the heaviest rainfall occurs in the summer half of the year, with pronounced maxima usually in June or July (and less frequently in September), and pronounced minima in December and January. Nanking is unusual in showing a secondary maximum in April. Chu attributes this to the increased number of cyclones moving out the Yangtze Valley at this time of year.

The big fact remains, however, that precipitation is heaviest in summer because then the winds are prevailingly from the southeast and are bringing in relatively large quantities of water vapor. As these winds are forced to ascend either by mountains or by the process of convection, heavy downpours are the result. In the winter, however, cold winds with little moisture are blowing out of the continental interior and are being made relatively drier as they are warmed in their descent from the highlands to the lowlands.

Chu, in discussing the normal conditions of rainfall in Nanking, states that the following description "applies equally well to Nanking and the whole Yangtze Valley," From the middle of June to the middle of July "the sky remains wholly overcast with clouds, and more or less rain falls every day. The air is so moist that walls and pavements become damp and furniture and clothes get moldy. The weather is indeed depressing and unpleasant." After the middle of July the weather is less rainy, and intervals of fine weather are frequent.

Probably even Nanking does not always experience such excessive dampness, records showing that the rainfall of this station is quite variable. For instance, in 1914 the total for June and July was less than 4 inches, or only 23 per cent of the normal for those two months. On the other hand, conditions must occasionally be even worse than Chu has indicated, for in 1915 nearly 24 inches of rain fell during these same two months; this was 160 per cent more than the normal.

In general this arrangement of summer rains and winter droughts is fortunate for China, because the rains come during the season when they are most needed for crops. Unfortunately, however, average conditions are far from dependable, as this case of Nanking would seem to indicate. In fact, it is quite rare when any considerable part of the Republic experiences an approximation of these average conditions. Either the rain comes too early or too late, or else too much comes in too short a period or fails altogether. It appears that some portion of the country annually suffers from droughts or floods ranging from inconsequential to very severe ones.

Droughts are most common in north China, less frequent in central China, and rarely occur in southern China. In the north the amount of rainfall under normal conditions is none too heavy; hence, even a slight diminution in the amount received during any period of the growing season causes hardship. For instance, in 1902 only 10 inches of rain fell at Tientsin; this is less than that received in most of our semiarid West. In 1920 this same station recorded only 11 inches; and it was during this year that most of northern China, an area of nearly 400,000 square miles and involving from 30 to 40 millions of people, received less than half of the average amount of rainfall. Many places in this region received

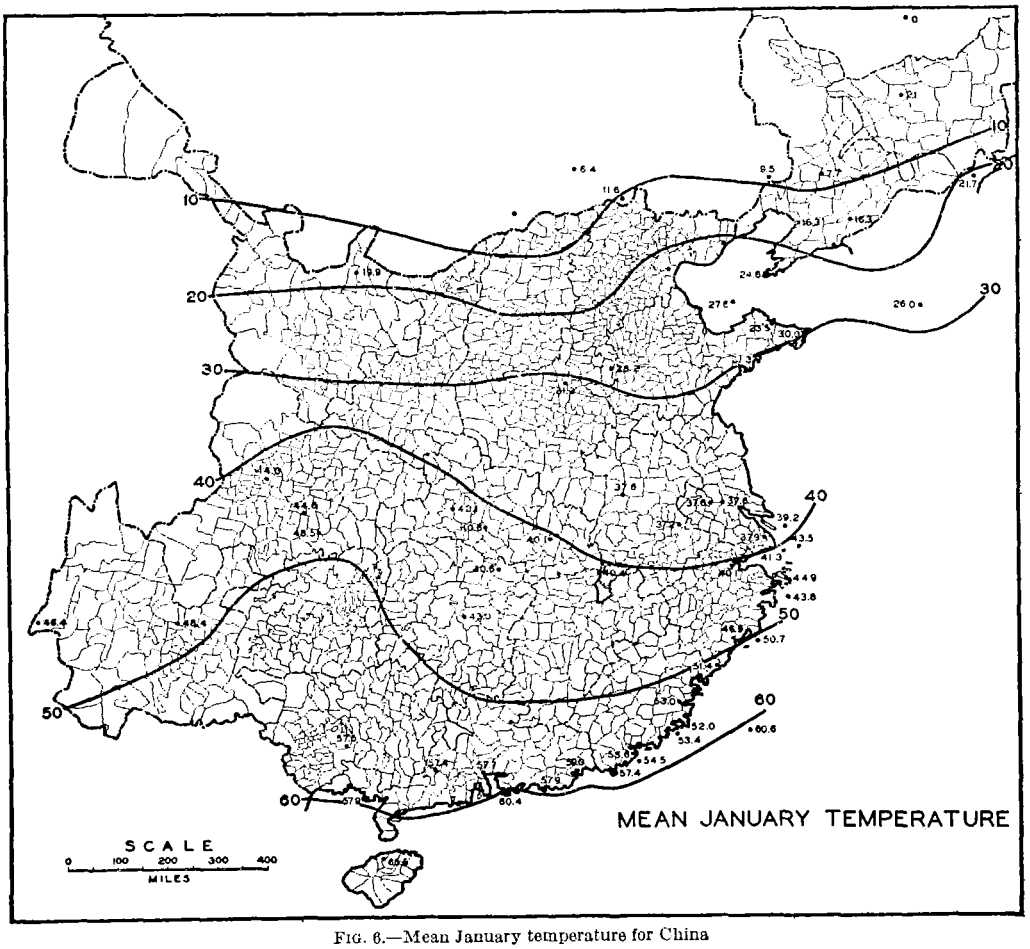

FIG. 6.—Mean January temperature for China

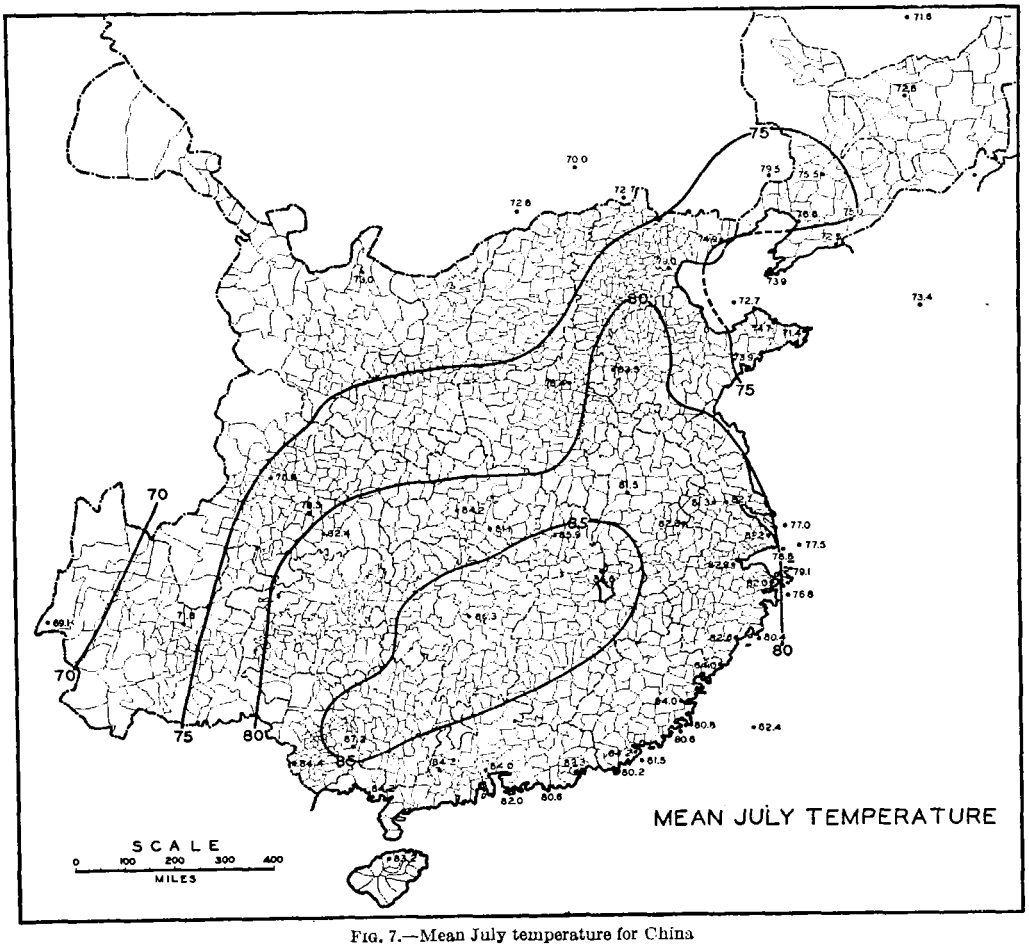

FIG. 7.—Mean July temperature for China

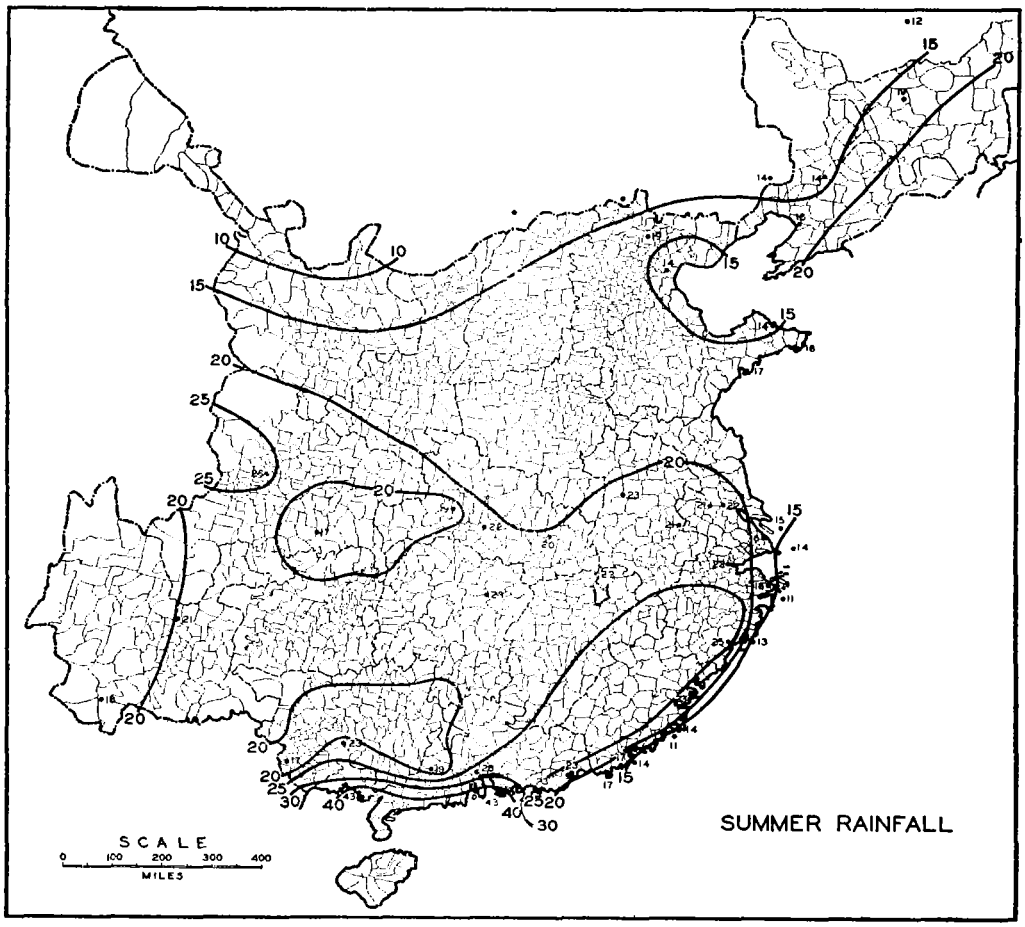

FIG. 8.—Mean summer rainfall for China

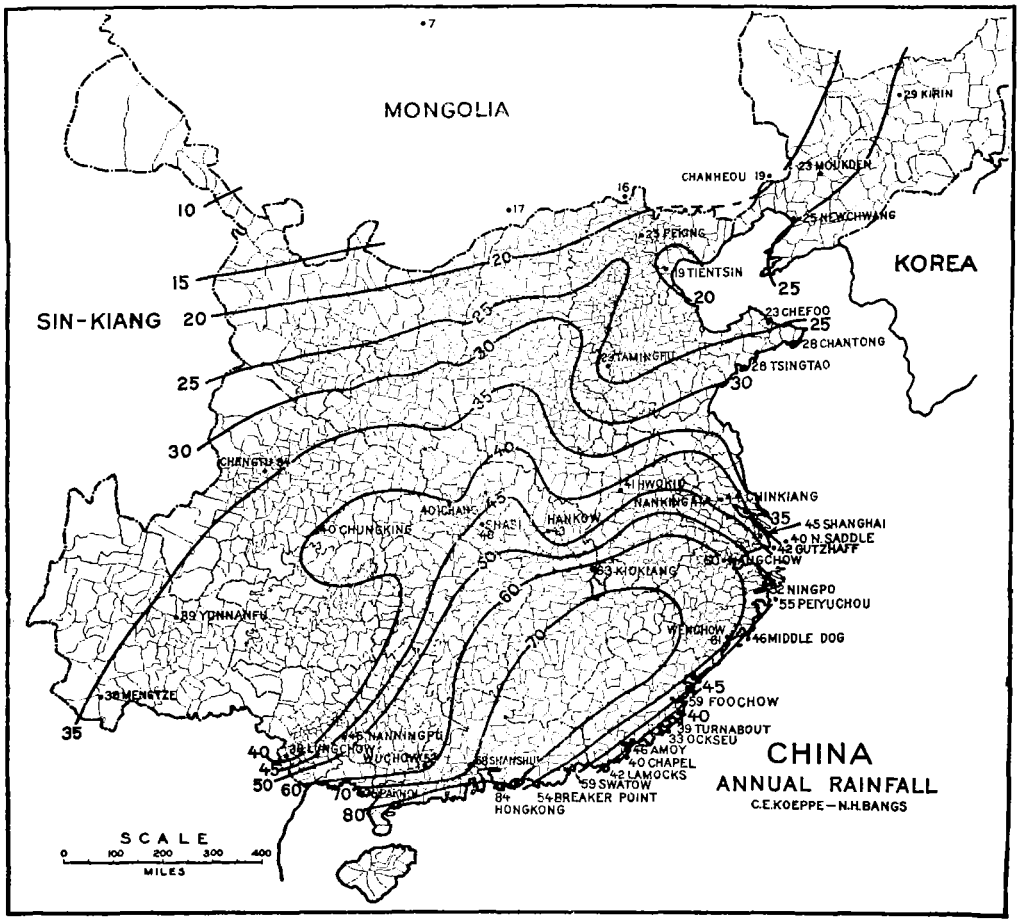

FIG. 9.—Mean annual rainfall for China

little or no rainfall during that year; and it was reported that the people had to resort to eating thistles, ground corncobs, and bark from trees. One writer who visited this region said that there was "not a leaf, a blade of grass, or a twig" in all four Provinces of northern China; for "a blade of grass no sooner made its appearance than it was pounced upon by a starving Chinese." Probably this is exaggerated.

It is true, however, that droughts of varying degrees of intensity occur at frequent intervals, especially in this northern sector. Serious crop failures and resulting famines are therefore just as frequent. The Government sometimes recognizes the seriousness of these by remitting all or a part of the taxes of the affected area. On the other hand, too much rain may come in too short a period and the people then must contend with floods. In fact, in this same region of north China, destructive floods occurred in 1917, only three years before the severe drought of 1920. Records show that the Chihli plain region may expect a flood once in six or seven years; this region is probably more subject to this sort of calamity because of the canal which connects Tientsin with a tributary of the Yellow River.

There are really three fundamental causes of floods here in northeastern China—first, erratic rainfall; second, deforestation; and third, the flat topography. In many places in this region the surfaces of the rivers are well above the general level of the plain and held in their courses only by natural or artificial dikes or levees.

In 1924 thousands of square miles of land were flooded. At one station in the district 23 inches of rain fell in 33 hours, and 9 inches of this came in 9 hours. This heavy downpour, coming as it did during the season when there was most rainfall, worked great havoc. Add to this the fact that water frequently remains on the land for months with the consequent drowning of any growing crops, and you have a measure of the destruction of property. The destruction is not confined to animals and crops; these floods also take their toll of human life. A definite and consistent national policy of reforestation and diking is the only adequate way of dealing with these floods, for rains will doubtless continue to be erratic. So far, only a little diking has been done, and almost no reforestation.

No treatment of the climate of China would be complete without some consideration of the typhoons, those violent tropical cyclones which so frequently ravage the southern coast. They loom large in Chinese history. Just as the Spanish Armada was destroyed by a violent cyclone in the English Channel, so a vast Chinese fleet of 3,500 ships assembled by the great Emperor Kublai Khan in the summer of 1281 for the invasion of Japan was totally destroyed by a typhoon. Of the 100,000 men who embarked on that fated expedition, only 3 returned. Perhaps the most violent storm of recent years was the so-called Swatow typhoon of August 1922, when 40,000 Chinese perished from the effects of the winds and water. As the center of the storm passed over the city the barometer fell to the unprecedentedly low level of 27.53 inches. The wind blew for two hours at an estimated rate of 100 miles an hour; and, as the center of the storm passed and the wind shifted from north to south, a great tidal wave inundated the city, drowning the closely packed Chinese inhabitants like rats. An interesting comparison might be made with the hurricane which visited Miami in September, 1926, when the barometer fell to 27.61, the lowest pressure ever recorded in the United States. Here, also, the wind blew at a speed of more than 100 miles an hour for two hours, first from the northeast and then from the southeast. From 8 to 16 inches of rain fell during the storm.

Unfortunately, China suffers from more frequent visitations by these tropical cyclones than does the United States. Chu found that during the 12-year period from 1904 to 1915, 54 typhoons struck the Chinese coast. Of these 54 all but 9 occurred in July, August, and September, and all but 3 entered the coast south of the twenty-eighth parallel. Thus, late summer is the most dangerous time, and southern China is the particular sufferer, for the typhoon loses much of its intensity as soon as it passes inland. Yet, once inland it may not die out; but, taking on the characteristics of an extratropical cyclone, it may pass northeastward over the interior and bring heavy rains to central and even to northern China. Most of the typhoons which visit China have their origin in the Pacific Ocean in the vicinity of the Caroline and Ladrone Islands.

M. A. GIBLETT ON LINE-SQUALLS [1]

"Squall" is defined as a sudden and violent gust, a blast or sharp storm of wind. The word "gust," it would seem, had been used earlier than "squall" and the implication is that it connoted a rise of wind of shorter duration than was implied by "squall." Some degree or precision was first given to these words as applied to wind when, after their intrusion into the vocabulary of the meteorologist, the pressure-tube anemometer was invented, an instrument that gives a continuous record of the wind and its fluctuations.

The "line-squall" is defined as a series of squalls occurring simultaneously along a line sometimes hundreds of miles long, advancing across the country at variable rates of speed. To such phenomena the word "line-squall" has been applied. The expression is synonymous with "wind-shift line" as used in the United States.

The characteristic manifestations of a line-squall on the ground are—

A sudden and rapid change of wind direction.
Heavy rain (or hail or snow).
Thunder and lightning.
A sunden fall of temperature.
A sudden or rapid rise of relative humidity.
A very rapid rise of barometric pressure during the passage.

The term "line-squall" is broadly applied to the ensemble of occurrences above listed.

The author considers the rapid fall of temperature as the basic characteristic of the phenomena and so treats the subject.

The fall of temperature is due to the arrival at the moment of a distinct colder mass of air which replaces the previously existing warmer current, and the line-squall is the physical result of this action. Accordingly, the basis of all that follows is the consideration of events when relatively cold masses of air impinge on relatively warmer ones. This brings into prominence the element temperature, which, at least from the point of view of airships, whether moored or in flight, is hardly second in importance to wind.

[1] Line-squalls, by M. A. Giblett, M. Sc. (Lond.). The Journal of the Royal Aeronautical Society, 198:509-549. June, 1927.

The author, who is superintendent airship meteorology division, Air Ministry, presents a very comprehensive discussion of line-squalls, from which the material here presented is abstracted.—*Editor.*